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PRELIMINARY INVESTIGATIONS ON DRY, COLD STORAGE OF SOUTHERN PINE SEED

by

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The Occasional Papers of the Southern Forest Experiment Station present information on current southern forestry problems under investigation at the Station. In some cases these contributions were first presented as addresses to a limited group of people, and as "occasional papers" they can reach a much wider audience. In other cases, they are summaries of investigations prepared especially to give a report of the progress made in a particular field of research. In any case, the statements herein contained should be considered subject to correction or modification as further data are obtained.

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Adequate methods of maintaining a high degree of viability in southern pine seed during storage are urgently needed. The Federal nurseries in the South use annually about 15 tons of southern pine seed, State and private nurseries use many more tons, and an increasing demand is in prospect. The annual collection of such quantities of seed is difficult or impossible, however, because the production of good seed crops by southern pines varies greatly with the season and the locality. The following tabulation of the longleaf cone crops for 2 successive years emphasizes this point:

Locality	1935 crop[1]	1936 crop[2]
Southern South Carolina	Fair to good	Definitely poor
Central and south Georgia	Good	Poor to spotty
Florida	Local variations extreme	Definitely poor
Central and south Alabama	Fair to good	Poor to spotty
South and southeast Mississippi	Very heavy	Poor to spotty
Southeast Louisiana	Very heavy	Poor to spotty
Central Louisiana	Very heavy	Definitely poor
East Texas	Very heavy	Poor to spotty

In years when the crop is a failure in one place but good in another, the deficit might be made up in one region by obtaining seed from an area of heavy production, but it is becoming increasingly evident that in many places local strains of forest trees are better for planting than those imported from a distance. This places a premium on local seed and emphasizes the need for storage methods that will maintain high viability in the large quantities of seed collected locally in years of good production.

There are in the files of the Southern Forest Experiment Station, and to a less extent in scattered publications, the results of several "exploratory" storage tests of southern pine seed. Pending publication of more comprehensive studies, the information obtained from these preliminary studies should be of interest and in some instances of direct practical benefit to individuals and agencies confronted with seed-storage problems. In the CCC program in particular, it is imperative that costly and meager supplies of seed be conserved by correct methods of storage. It is the purpose of this paper, therefore, to evaluate the results of the Station's storage tests and to compare them with

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1/ Wakeley, Philip C. Estimate of the 1935 cone crop of southern pines. Southern Forest Experiment Station. (Mimeographed) August 27, 1935.
2/ Wakeley, Philip C. Estimate of the 1936 cone crop of southern pines. Southern Forest Experiment Station. (Mimeographed) August 22, 1936.

results obtained by other workers, so that they may be available for immediate use. Results of early work on storage of southern pine seed are presented in considerable detail because it is thought that users of seed will find these details very illuminating.

For several reasons, most emphasis has been placed on methods of storing longleaf pine seed. Because of the relatively small number of seed per pound in this species, any reduction in germination percentage results in a disproportionately great increase in the cost per thousand of seedlings produced. With longleaf seed at $1.00 a pound, a rather common price, the cost per thousand trees for seed alone rises from $0.36 if 70 percent of the seed produce seedlings, to $0.63 per thousand if the seed viability drops to 40 percent, and to the astounding figure of $2.50 per thousand trees if effective germination is only 10 percent. Nevertheless, longleaf seed is particularly likely to deteriorate in storage.

Early attempts at the Southern Forest Experiment Station to store southern pine seed made use of a variety of containers, such as sealed glass jars, paper bags, and even sealed wax-paper bags. Some seed lots were disinfected with formaldehyde, other lots were untreated. No record was made of the moisture content of the seed at time of storing, nor was the germination percentage (measure of initial seed quality) always determined for the fresh seed. Temperatures during the storage period were disregarded. A concise, quantitative summary of experiments during this early period cannot be made, but the nature of the results is readily apparent when the data are grouped loosely by species and by treatment previous to storage. The results were highly erratic and generally unsatisfactory (see table 1). The viability of longleaf seed was usually greatly reduced within a year. For instance, the germination percentage of a longleaf seed lot dropped in 1 year from an initial value of 49 percent to 14 percent when stored, without disinfection, in sealed glass; yet the following season, the germination percentage of a lot under comparable storage conditions with 77 percent initial germination dropped in 1 year to 2.4 percent. On the other hand, longleaf seed from the 1925 crop, with a germination of 75 percent when fresh, when stored in sealed glass after treatment with formaldehyde kept remarkably well for 1 year (germination 74.0 percent) and moderately well for 2 years more (41.5 percent and 42.8 percent germination after 2 and 3 years, respectively). Since the longleaf seed were usually dried by air currents from an electric fan after treatment with formaldehyde, it was thought that this thorough drying might have been the factor responsible for the good preservation of these seed lots. This led to measurements of seed moisture content before storage, and in 1935 a cautious surmise was expressed (3)[3/] that moisture content was important in the storage of longleaf pine seed.

Slash and loblolly seed in various containers gave somewhat erratic results—in general, rather poor—but this cannot be attributed entirely to the storage methods, as the germination periods in successive years were of unequal length. Both slash and loblolly seed tend to become dormant, and to require long periods for complete germination, but they nevertheless remained viable longer than longleaf seed. This tendency of the smaller seed to keep better than the larger ones was another clue to the possible importance of moisture content, since the proportion of hard, dry seedcoat to moist kernel is greater in small seed and therefore the moisture content of the seed is lower.

3/ Figures in parentheses refer to Literature Cited, page 19.

Table 1. - Summary of results of storage in various containers and at uncontrolled temperatures as shown by best available germination tests (1922-25)

Cone sublot no.	Storage method	Germination medium	Percent of germination[1]					
			Fresh	Years in storage				
				1	2	3	4	5
		LONGLEAF						
- 1922	Sealed glass-2nd year	Sand & soil		5.0				
		Sand			0.0			
5 1924	Sealed glass, not disinfected[2]	Sand & soil	49.0					
		Sand		14.0				
		Sand			0.3			
5 1924	Unsealed paper, not disinfected	Sand & soil	49.0					
		Sand		19.0				
		Sand			0.0			
		Paper towel				0.0		
5 1924	Sealed glass, formaldehyde	Sand & soil	49.0					
		Sand		36.0				
		Sand			6.2			
5 1924	Paper bag, formaldehyde	Sand & soil	49.0					
		Sand		15.5				
5 1924	Sealed wax paper, not disinfected	Sand & soil	49.0					
		Sand		14.0				
		Sand			5.5			
		Paper towel				0.0		
2a 1925	Sealed glass, formaldehyde	Sand	75.0					
		Sand		74.0				
		Paper towel			41.5			
		Sand				42.8		
		Sand					0.0	
		Sand						0.0

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Table 1. - Summary of results of storage in various containers and at uncontrolled temperatures as shown by best available germination tests (1922-25) - Cont'd.

Cone sublot no.	Storage method	Germination medium	Percent of germination[1] Fresh	Years in storage 1	2	3	4	5
		LONGLEAF (Cont'd.)						
2a 1925	Sealed glass, not disinfected	Sand	77.0					
		Sand		2.4				
		Paper towel			0.0			
		Sand				0.0		
		Sand					0.0	
		Sand						0.0
2a 1925	Unsealed ash can	Sand	77.0					
		Sand		3.2				
		Paper towel			0.0			
2a 1925	Unsealed paper	Sand	77.0					
		Sand		2.8				
		Paper towel			0.0			
2a 1925	Buried 2½ feet deep	Sand	77.0					
		(None[3])		-				
		SLASH						
- 1922	Sealed glass	Sand			0.0			
- 1923	Sealed glass	Sand		24.0				
		Jacobsen			5.0			
		Compost				6.2		
- 1924	Sealed glass, not disinfected	Sand		66.0				
		Compost			1.0			
- 1924	Paper bag, not disinfected	Sand		61.0				
		Compost			2.3			
		Paper towel				0.0		
- 1924	Sealed glass, formaldehyde	Sand		63.0				
		Compost			8.8			
- 1924	Paper bag, formaldehyde	Sand		71.0				

(Continued on following page)

Table 1. - Summary of results of storage in various containers and at uncontrolled temperatures as shown by best available germination tests (1922-25) - Cont'd.

Cone sublot no.	Storage method	Germination medium	Percent of germination[1]					
			Fresh	Years in storage				
				1	2	3	4	5
		SLASH (Cont'd.)						
– 1924	Unsealed ash can	Sand		66.0				
		Compost			3.8			
		Paper towel				1.0		
– 1924	(Spring, 1925) Ash can, commercial storage	Sand		64.0				
– 1924	Sealed wax paper	Sand		71.0				
		Compost			1.4			
		Paper towel				0.0		
		LOBLOLLY						
– 1922	Sealed glass	Sand			20.0			
– 1923	Sealed glass	Sand		13.0				
		Jacobsen			2.0			
		Sand				0.0		
– 1923	Paper sack	Sand		58.0				
		Sand			40.0			
		Sand				3.7		
– 1923	Unsealed ash can	Sand			44.0			
		Sand				8.5		
		Paper towel					0.0	
– 1924	Sealed glass, not disinfected	Sand	48.0					
		Sand		13.0				
		Sand			0.0			
– 1924	Paper bag, not disinfected	Sand	48.0					
		Sand		19.0				
		Sand			0.4			
		Paper towel				0.0		
– 1924	Sealed glass, formaldehyde	Sand	48.0					
		Sand		14.0				

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Table 1. - Summary of results of storage in various containers and at uncontrolled temperatures as shown by best available germination tests (1922-25) - Cont'd.

Cone sublot no.	Storage method	Germination medium	Percent of germination[1] Fresh	Years in storage 1	2	3	4	5
			LOBLOLLY (Cont'd.)					
-	Paper bag,	Sand	48.0					
1924	formaldehyde	Sand		11.0				
-	Sealed wax paper,	Sand	48.0					
1924	not disinfected	Sand		20.0				
		Sand			0.0			
		Paper towel				0.0		
42h	Sealed glass,	Sand	57.0					
1925	not disinfected	Sand		31.6				
		Paper towel			1.5			
		Sand				12.0		
		Sand					0.0	
		Sand						0.0
42h	Paper bag,	Sand	57.0					
1925	not disinfected	Sand		43.8				
		Paper towel			16.0			
42h	Sealed glass,	Sand	57.0					
1925	formaldehyde	Sand		25.6				
		Paper towel			8.5			
		Sand				24.0		
		Sand					12.0	
		Sand						3.0
42h	Unsealed ash can	Sand	57.0					
1925		Sand		46.2				
		Paper towel			10.0			
			SHORTLEAF					
-	Sealed glass	Sand		10.0				
1923		Jacobsen			3.0			
		Soil				1.4		
3	Unsealed paper	Jacobsen	33.0					
1924	sack	Sand		17.0				
		Soil			0.0			
		Paper towel				0.0		

(Continued on following page)

Table 1. - Summary of results of storage in various containers and at uncontrolled temperatures as shown by best available germination tests (1922-25) - Cont'd.

Cone sublot no.	Storage method	Germination medium	Percent of germination[1/] Fresh	Years in storage 1	2	3	4	5
			SHORTLEAF (Cont'd.)					
62h	Sealed glass,	Sand	82.0					
1925	not disinfected	Sand		63.6				
		Paper towel			0.0			
		Sand				0.0		
		Sand					0.0	
		Sand						0.0
62h	Paper sack,	Sand	82.0					
1925	not disinfected	Sand		47.0				
		Paper towel			2.0			
62h	Sealed glass,	Sand	82.0					
1925	formaldehyde	Soil		30.8				
		Paper towel			32.0			
		Sand				30.0		
		Sand					3.0	
		Sand						4.0
62h	Unsealed ash can	Sand	82.0					
1925		Sand		39.4				
		Paper towel			1.5			
62h	Sealed wax paper	Sand	82.0					
1925		Soil		13.0				
		Paper towel			1.5			

1/ Germination percentage is based on all seed sown, as cutting tests of ungerminated seed were lacking in many instances. Length of germination periods varied from 33 to 150 days; in all cases, tests were run longer than necessary for essentially complete germination.

2/ The annotations "formaldehyde" and "not disinfected" indicate, respectively, samples rinsed in weak formaldehyde solution before storing, and matched samples stored without disinfection as checks. Lack of annotation indicates that the sample was neither treated nor matched with a treated sample.

3/ Seed decayed during first year; no germination tests made.

The first consistent successes in maintaining viability of longleaf seed resulted from holding the samples in cold storage. Seed held in a sealed glass jar under refrigeration gave as high germination at the end of 2 years as when fresh, whereas the same seed stored at room temperatures, in a variety of containers, and after several types of disinfection, were much reduced in viability after 1 year and were completely spoiled at the end of 2 years. The details of storage and percentages of germination are given in table 2, which also gives the data on lots stored in an ordinary ice box (at about 55° F.), in a commercial fish-packing plant (cooled by ice), and in a mechanical refrigerator. The seed containers were of various types: sealed glass jar, semi-sealed jar, screw-top can, and paper sack. Results at the end of a year were uniformly good. Cold-storage seed lots tested in 1936 and 1937 were obtained from Federal and State forest nurseries; these had usually been stored in commercial cold-storage warehouses. Data on storage containers and temperatures are meager, and the germination percentages of the fresh seed were usually not available, but the generally good condition of the seed after 1-3 years is apparent.

The preservative value of low temperatures is further borne out by a report[4] of successful storage of longleaf pine seed in air-tight jars, for 1-3 years, in a fairly cool basement at the Institute of Forest Genetics at Placerville, Calif.

Longleaf pine seed stored in paper bags in a refrigerated room at the Lake States Forest Experiment Station in 1929-30 (sample number 12, 1929, table 2) gave higher germination at the end of a year than a portion of the same seed lot stored in a sealed glass jar (sample number 10, 1929, table 2). It has been predicted that the reverse would happen, because the drying effect of the refrigeration room on the seed exposed in a paper sack was thought to be harmful. Since the thoroughly dried seed kept better, the moisture content during storage was again thought to be an important factor.

The data in table 2 do not prove or disprove the adequacy of a cold environment as a storage method, because of the lack of experimental design, matched samples for different treatments, or an attempt at check or control lots. Table 2 does, however, contain valuable contributory evidence on the subject, since it does show a noteworthy number of seed lots held at low temperatures that were good after 1 or more years.

A much more systematic and detailed test of low-temperature versus air-temperature storage, over a period of 6 years, showed conclusively that cold storage was effective in maintaining viability of longleaf, slash, loblolly, and shortleaf seed (table 3). The seed were stored in semi-sealed glass jars in lots of approximately 750-1,000, at room temperature and at 33°-35° F. A separate jar was put up for each year of testing, so that conditions within the jar would not be changed by admission of air during withdrawal of the test sample. The prevailing high germination values for the cold-storage lots of all species, and the practically complete failures of all the room-temperature lots after 2 years in storage, demonstrated conclusively the beneficial effects of storage at low temperature.

4/ In a letter from Lloyd Austin, Director, Institute of Forest Genetics, to Philip C. Wakeley, August 23, 1933.

Table 2. - Tests showing the effects of cold storage for one or more years

Seed sample number	Storage temperature and environment	Container	Germination percent			
			Fresh	Years of storage		
				1	2	3
		LONGLEAF				
1/1927						
(9	Normal room	Unsealed ash can	76.5	52.0	2.0	0.0
(10	Normal room	Sealed glass jar	76.5	16.0	0.0	0.0
(11 (	25°-30° F. (Mechanical refrigeration)	Sealed glass jar	76.5	75.8	77.6	(Seed stolen)
(12	Normal room	Sealed glass jar2/	76.5	(Spoiled)	-	-
(13	Normal room	Sealed glass jar3/	56.5	26.8	0.4	-
(14	Normal room	Sealed glass jar4/	60.0	9.4	0.0	0.0
1928						
(27 (	About 55° F. (ice box)	Screw-top can	73.5	67.6	66.5	-
(28	Normal room	Unsealed ash can	76.0	26.8	0.0	-
1929						
(10 (	32° F. (Mechanical refrigeration)	Sealed glass jar	55.6	54.8	-	-
(11	Normal room	Sealed glass jar	55.6	47.6	-	-
(12 (	32° F. (Mechanical refrigeration)	Paper sack	55.6	60.0	-	-
(13	Normal room	Paper sack	55.6	26.0	-	-
(21 ((	Ice refrigeration (Fish packing plant)	Can	49.2	45.0	-	-
(21	Normal room	Unsealed ash can	49.2	0.0	-	-
(23 ((	Ice refrigeration (Fish packing plant)	Can (?)	46.8	35.0	-	-
(23	Normal room	Paper sack	46.8	0.0	-	-
1936						
1502	Cold storage (State nursery)	-	-	-	64.0	-
1503	Cold storage (State nursery)	-	-	39.2	-	-
1506	Cold (Federal nursery)	Galvanized iron can	-	41.5	27.8	-
1507	Cold (Federal nursery)	-	-	5.9	-	-

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Table 2. - Tests showing the effects of cold storage for one or more years - Cont'd.

Seed sample number	Storage temperature and environment	Container	Germination percent			
			Fresh	Years of storage		
				1	2	3
		LONGLEAF (Cont'd.)				
1937						
1515	Cold (Federal nursery)	Galvanized iron can	73.0	52.7	-	-
1516	Cold (Federal nursery)	Galvanized iron can	-	28.5	-	-
		SLASH				
1930						
145a	34°-40° F.	Air-tight friction-top tin	-	79.6	-	-
1936						
2501	Cold (State nursery)	-	-	-	65.2	60.8
2502	Cold (State nursery)	-	-	52.8	-	-
2505	38° F. (Federal nursery)	Galvanized iron can	-	84.8(?)	70.3	71.7
2506	38° F. (Federal nursery)	Galvanized iron can	-	55.1	-	-
2507	Cold (Federal nursery)	-	-	72.4	-	-
1937						
2506	Cold (Federal nursery)	Galvanized iron can	80.7	70.3 (Strat.)	-	-
2504	Cold (Federal nursery)	Galvanized iron can	-	-	-	71.7
2504	Cold (Federal nursery)	Galvanized iron can	-	-	-	72.2 (Strat.
		LOBLOLLY				
1936						
3501	Cold (State nursery)	-	-	-	40.8	-
3502	Cold (State nursery)	-	-	44.8	-	-
3506	Cold (Federal nursery)	-	-	68.8	-	-
1937						
3509	Cold (Federal nursery)	-	-	42.4	-	-
3510	Cold (Federal nursery)	-	-	59.2	-	-

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Table 2. - Tests showing the effects of cold storage for one or more years - Cont'd.

Seed sample number	Storage temperature and environment	Container	Germination percent			
			Fresh	Years of storage		
				1	2	3
		SHORTLEAF				
1930						
301	34^{o}-40^{o} F.	Air-tight, friction-top tin	-	86.0	-	-
1937						
(4510 (	30^{o} F. (Federal nursery)	Sealed can	64.0	-	56.0	-
(4511 (	Seed room (Federal nursery)	Mason jar	64.0	-	60.8	-

1/ Brackets indicate samples drawn from the same original seed lot, and therefore comparable until treated as indicated in the table.

2/ Seeds were packed in sphagnum moss moistened with approximately 1/20 normal salicylic acid solution.

3/ Jars and seed were sterilized with DuPont Semesan, 33 mg. to approximately 80 g. of seed.

4/ Jars and seed were sterilized with formaldehyde (3/10 percent or 1 fluid ounce per gallon of water for 10 minutes). Seeds were then dried with an electric fan.

Table 3.- Germination percentages of initially comparable samples[1] of longleaf, slash, loblolly, and shortleaf pine seed kept in semi-sealed containers in cold storage and at room temperature for 1 to 6 years

Years stored	Date test set up	Total percent germination[2]		Percentage sound at end of test		Total,% germinated plus % sound		Days duration of test	
		Cold	Air	Cold	Air	Cold	Air	Cold	Air
				Longleaf					
0	Mar. 15, 1932	55.6	55.6	0.4	0.4	56.0	56.0	50	50
1	Mar. 6, 1933	41.2	8.8					45	45
2	(Test omitted)								
3	Dec. 3, 1934	61.6						46	
4	Apr. 23, 1936	26.0	0.0	0.0		26.0		70	
5	Jan. 8, 1937	48.0	0.0	0.8	0.0	48.8	0.0	67	67
6	Nov. 15, 1937	46.0	0.0	0.4	0.0	46.4	0.0	80	80
				Slash					
0	Mar. 15, 1932	71.2	71.2	18.4	18.4	89.6	89.6	50	50
1	Mar. 6, 1933	85.2	49.6					35	45
2	(Test omitted)								
3	(Nov. 28, 1934 (Dec. 3, 1934	95.6	0.4	0.4		96.0		>94	
4	Apr. 23, 1936	56.4	0.0	28.8		85.2		69	
5	Jan. 8, 1937	95.6	0.0	0.4	0.0	96.0	0.0	160	160
6	Nov. 15, 1937	93.2	0.0	3.2	0.0	96.4	0.0	125	125
				Loblolly					
0	Mar. 15, 1932	4.0	4.0	81.2	81.2	85.2	85.2	50	50
1	Mar. 6, 1933	4.8	1.2					35	35
2	(Test omitted)								
3	Dec. 3, 1934	64.8		14.8		79.6		>94	
4	Apr. 23, 1936	43.2	8.4	25.2		68.4		69	64
5	Jan. 8, 1937	73.2	0.4	8.4	1.2	81.6	1.6	200	200
6	Nov. 15, 1937	71.6	0.4	7.2	0.0	78.8	0.4	125	125
				Shortleaf					
0	Mar. 15, 1932	68.8	68.8	26.8	26.8	95.6	95.6	50	50
1	Mar. 6, 1933	61.6	56.8					45	45
2	(Test omitted)								
3	(Nov. 28, 1934 (Dec. 3, 1934	94.4	0.8	0.8		95.2		>94	
4	Apr. 23, 1936	78.8	0.0	10.8		89.6		69	
5	Jan. 8, 1937	81.6	0.0	10.4		92.0		67	60
6	Nov. 15, 1937	86.8	0.0	5.2	0.0	92.0	0.0	80	80

1/ Original seed sample numbers: Longleaf, 1001C, 1931; Slash, 2001C, 1931; Loblolly, 3001C, 1931; Shortleaf, 4001C, 1931.

2/ Each figure represents the result of a 250-seed germination test on a "standard" peat mat, without pretreatment of the seed. The laboratory environment (daily temperature range, amount of light, etc.) was not uniform-note various dates of testing.

In this test the percentages obtained from cold-storage seed in the 4th year were below those obtained in the 3d and 5th years, possibly owing to the fact that the seed were tested late in April instead of earlier in the spring. Samples of the 1927 longleaf seed crop, withdrawn from storage at room temperature at monthly intervals and tested in sand, declined sharply in viability at the end of May (table 4). Part of the longleaf seed of the 1928 crop, as shown in table 5, was stored, as in 1927, in paper sacks in a covered can at room temperature, and part was stored in screw-top metal cans in an ice box. Pairs of samples were withdrawn and germinated at monthly intervals for 13 successive months. Since both room-temperature and cold-storage lots show the same sharp decline in total germination between the May and June tests, it seems likely that the low germinability of the 4th-year sample of the 6-year storage test was due to testing late in the season. This brings out the fact that to obtain entirely comparable results in storage studies, yearly germination tests in ordinary laboratories must be run not only on the same type of medium but also at approximately the same season of the year.

The criticism may be raised that the high germination percentages shown in table 3 for seed held in cold storage were obtained only after germination periods as long as 125, 160, and 200 days. Since this experiment was started, however, it has been shown definitely that moist, cold stratification before sowing ordinarily will enable similar dormant seed to germinate almost, if not quite, as rapidly as fresh seed. The use of moist, cold stratification was considered for the later tests of the series, but was finally omitted in order to continue the tests by means of the same germination technique used at the start. The significant fact is not that the seed held at cold storage required 100 or more days to germinate, but that it finally attained a high percentage of germination, while seed stored at room temperature and then exposed to a similar environment for an equally long period failed to germinate.

The next advance in seed-storage methods was the regulation of moisture content of the seed. This varies considerably under different conditions, especially in longleaf pine (table 6); seed freshly dissected from ripe (but unopened) cones may contain as much as 40 percent moisture, based on dry weight, seed that have fallen from cones opened naturally by air-drying are still very moist, and seed from cones opened by kiln-drying also may be surprisingly moist. Several investigators have worked on the influence of this factor on keeping qualities and germination. Coile (2), using closed chambers whose atmospheres were held at constant relative humidities by means of solutions of different concentrations, brought slash pine seed to moisture contents of 7.5, 11.5, 22.5, and 32 percent. At the end of storage for 1 year at room temperature in sealed glass tubes, the lots at 32 and 22.5 percents were covered with molds and failed to germinate; that at 11.5 percent gave 57 percent germination in 40 days; and that at 7.5 percent gave 82 percent germination in 20 days. Barton (1), working with longleaf, slash, loblolly, shortleaf, and other pines, found that in some instances thorough air-drying of seed, together with sealed storage at low temperatures, was effective in maintaining viability for as much as 7 years. Artificial desiccation with calcium oxide was ineffective or harmful; but storage under vacuum was favorable to retention of viability even at room temperature.

Table 4.- Germination tests of longleaf pine seed (1927 crop, cone sublot 1a) removed from air temperature storage at monthly intervals

Storage[1/] (months)	Date tested	Germination[2/]		
		Final percentage		Days of test
		All seed	Full seed	
1	Dec. 1927	66.5	-	21
3	Feb. 1928	76.5	84.5	30
4	Mar. "	69.0	83.1	30
5	Apr. "	74.4	87.6	25
6	May "	68.9	80.4	35
7	June "	22.7	24.0	30
8	July "	12.0	14.5	35
9	Aug. "	14.0	15.3	30
10	Sept. "	9.6	9.6	29
11	Oct. "	23.0	26.0	30
12	Nov. "	25.5	26.4	24
13	Dec. "	20.0	21.5	29

1/ Stored in paper sacks in unsealed galvanized iron ash can.
2/ Tested at Southern Forest Experiment Station, in standard sand flats. Each monthly test consisted of 200 seed.

Table 5. - Parallel germination tests of longleaf pine seed (1928 crop)[1] removed at monthly intervals from cold and from air temperature storage

Storage period (months)	Date test set up	Final germination percentage[2]				Days of test	
		All seed		Full seed			
		Cold[3]	Air[4]	Cold[3]	Air[4]	Cold[3]	Air[4]
0	Nov. 20, 1928	-	59.2	-	72.9	-	30
1	Dec. 31, 1928	78.0	74.5	89.6	85.6	22	25
2	Jan. 31, 1929	73.5	76.0	89.1	84.9	27	20
3	Feb. 28, "	73.5	71.0	85.0	85.0	22	20
4	Apr. 6, "	66.0	70.0	67.3	71.8	30	30
5	Apr. 30, "	73.5	65.0	81.7	76.9	35	35
6	May 31, " June 1, "	28.0	12.0	29.0	12.8	36	40
7	July 1, "	19.5	5.0	21.1	5.9	44	40
8	July 31, "	27.5	25.5	28.3	29.1	54	55
9	Sept. 4, "	52.5	25.0	57.7	26.3	51	55
10	Oct. 3, "	70.0	37.5	73.6	38.5	49	55
11	Oct. 31, "	77.5	43.5	86.1	48.6	42	50
12	Dec. 2, "	65.5	26.0	71.8	26.7	31	45
13	Jan. 21, 1930	67.6	26.8	74.5	28.4	38	60

1/ Cone sublot 2a, 1928, seed samples 27 (cold storage) and 28 (air temperature storage), 1928.

2/ Tested in standard sand flat, 200 seeds each test (except 250 seeds for Jan. 21, 1930 test of cold storage seed).

3/ In screw-top soil cans in domestic ice box, at approximately 55° F.

4/ In paper sacks in unsealed galvanized iron can, at room temperature.

Table 6.- Moisture content of longleaf pine seed

Extraction and treatment of seed	Percent moisture (based on dry wt.) Whole seed	Kernel only	Basis
Cones freshly collected, seed dissected out	40.7	64.5	10 seed
Seed dissected out several days after collection	35.3	49.2	10 seed
Cones air-dried for 2 weeks after collection	29.8	39.5	10 seed
Cones air-dried; moisture content determined upon release of seed from cones	(28.9	35.9	11 seed
	(28.0	38.6	19 seed
	(25.5	33.5	-
Cones air-dried at nursery	19.5	-	4 lots
Cones air-dried, seed air-dried 30 days	11.1	12.6	10 seed
Cones kiln-dried (130° F.), seed dewinged	15.7	-	4 lots
Cones kiln-dried (130° F.), seed with wings on	20.0	-	4 lots
Cones kiln-dried ("Charge 83")	21.2	-	4 lots
Cones kiln-dried	20.4	-	4 lots1/
Cones kiln-dried; seed tested at beginning of storage study	(22.5	-	4 lots1/
	(22.6	-	4 lots1/
Cones kiln-dried; seed used to pack cans and bags in storage study (dewinged	14.6	-	4 lots2/
(wings on	16.1	-	4 lots2/
Cones kiln-dried; seed stored in can (bottom	25.6	-	1 lot3/
(middle	23.8	-	1 lot3/
(middle	22.9	-	1 lot3/
(top	26.9	-	1 lot3/
(mixed	25.9	-	1 lot3/
Seed used in storage study (1927)	11.5	-	-
Cones kiln-dried (130° F.); seed redried in kiln	8.4	-	4 lots

1/ 100 seed each.
2/ 10 grams each.
3/ 50 grams.

Some nurserymen in Georgia have followed the practice of sunning their sacks of fresh seed 2 or 3 days a week from the time of extraction to the middle of March, then pouring the seed into carefully cleaned empty grease cans, screwing the tops on securely, and storing in pecan (cold-storage) warehouses. Both longleaf and slash pine seed have kept well for 2 years following this treatment.

Subsequent experiments at the Southern Station, to be described in detail in a forthcoming publication, have confirmed the beneficial effects on storage of longleaf seed of low temperature and low moisture content. The most significant single factor, as revealed by these tests, was moisture content; environment, of which cold storage was one type, was of secondary importance.

A small study was run in 1936-37 to determine seed deterioration at several degrees of wetness. Paired samples of longleaf seed with initial germination of 77.3 percent were reduced by air drying to five different moisture contents from about 22 percent to about 6 percent, as shown in table 7. One series of these samples was stored in sealed glass jars at room temperatures, and the other series at 38° F. At the end of 1 year, germination tests were made. The samples stored at room temperature, and having a moisture content of at least 9.5 percent, were almost or entirely spoiled, but the sample at 6 percent gave 48.8 percent germination, which was surprisingly good. This behavior is similar to that of the longleaf seed lots put up in 1925, and mentioned earlier in this discussion. In the 1925 series (table 1) the lots stored without extra drying in an unsealed ash can, in sealed glass (not disinfected), and in a paper sack were almost entirely spoiled in 1 year, just as were the 1936 lots having moisture contents of 9.5 percent or above. The lot treated with formaldehyde, and well dried before sealing in a glass jar, was in excellent condition after storing 1 year; in fact, it was more viable than the 1936 lot dried to 6 percent moisture content.

Of the samples in the 1936 series stored at 38° F., the three at the higher moisture contents were not entirely comparable with the others because they were not placed in cold storage immediately after sealing in jars. The sample at 9.5 percent germinated 56.8 percent, and the one at 6 percent germinated 66.4 percent, or almost as well as the fresh seed. The most interesting feature of the test was the retention of high viability of the seed at 6 percent, both at room temperature and in the cold.

The conclusions to be drawn from these (preliminary) studies and observations are: (1) that a reduction in seed moisture content by methods that will not injure the seed (e.g., by air-drying before a fan or in the sun) is distinctly beneficial in maintaining seed viability; and (2) that storage at low temperatures (approximately 30°-40° F.) also aids materially in preventing seed deterioration. The object of later experiments will be to delimit more closely the optimum ranges of moisture content and of low temperature, and to test the possibilities of combining the two; but until results of such experiments are available, the data embodied in this report should serve to point the way towards better storage methods.

Table 7.- Effect of moisture content upon keeping quality of longleaf pine seed held in sealed glass jars at room temperature and in cold storage

Initial moisture content, percent	Germination percentage 1/ after approximately 10 months at:-	
	Room temperature	38° F.
21.97	0.0	(12.4) 2/
17.85	0.0	(34.8) 2/
12.61	0.0	(59.6) 2/
9.50	0.8	56.8
6.02	48.8	66.4

1/ Germination percentage before samples were dried and stored was 77.3%.

2/ Held in sealed jars at room temperature for 8 to 15 days before being placed in refrigerator—hence not strictly comparable with other seed lots.

Literature Cited

(1) Barton, Lela V. Storage of some coniferous seeds. Contrib. from Boyce Thompson Inst. 7 (4): 379-404. 1935.

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(3) Wakeley, Philip C. Artificial reforestation in the southern pine region. U. S. Dept. Agr. Tech. Bull. No. 492, 114 pp. November 1935.